Betty Eells

Bill Mayhew

Bird Incubation
Sheets

Bird Incubation
Sheets

Code For Incubation Data
(Birds)

Each egg will possess three numbers:

First no. = number of clutch of that species.

Second no. = number of egg in the clutch.

Third no. = total number of eggs in the clutch.

Example: 2-1-6 = Second clutch of that species, first egg of clutch of 6.

I = previously incubated egg.

F = fresh egg.

D = interior of egg dark when candled—incubation far along.

V = vitelline circulation can be seen when candled.

Species: House finch (*Carpodacus mexicanus*)

Egg No.	Date Set	Date Hatched	Incubation Temp. (°F)	Incubation Humidity (%)	Egg Turning	Locality Collected	Remarks
1-1-6	4/23/58	—	100	65	Continuously	2 mi. E. Riverside, Riverside Co., Calif	(F) Motor broke-5/1/58 Emb. still alive-feather papillae visible-~1/2 grown
1-2-6	"	—	"	"	"	"	(F) Motor broke-5/1/58 Embryo as 1-1-6. Alive (Preserved)
1-3-6	"	—	"	"	"	"	(F) Motor broke-5/1/58 Embryo as 1-1-6. Alive (Preserved)
1-4-6	"	—	"	"	"	"	(F) Motor broke-5/1/58 Emb. w/op. ves. (dead)
1-5-6	"	—	"	"	"	"	(F) Motor broke-5/1/58 Emb. alive-limb buds well developed-similar to 1-1-6.
1-6-6	"	—	"	"	"	"	(F) Motor broke-5/1/58 Emb. w/op. ves. (dead)
2-1-5	"	—	"	"	"	"	(F)(?) Motor broke-5/1/58 Infertile
2-2-5	"	—	"	"	"	"	(I)(V) Found cracked 4/28; Embryo w/optic ves.
2-3-5	"	5/1/58	"	"	"	"	(I)(D) Motor broke-5/1/58 Hatched in vial
2-4-5	"	5/1/58	"	"	"	"	(I)(D) Motor broke-5/1/58 Hatched in vial
2-5-5	"	—	"	"	"	"	(I)(D) Motor broke-5/1/58 Egg pipped-emb. still alive-just ~ ready to hatch.

Species.

Egg No.	Date Set	Date Hatched	Incubation Temp. (°F)	Humidity (%)	Egg Turning	Locality Collected	Remarks

Reptile Incubation
Sheets

Reptile Incubation Sheets

SPECIES ________ TEMP (°C) ________ HUMIDITY% ________ [illegible] ________

CLUTCH NO ________ ♀ COLLECTED: DATE ________ LOCALITY ________

Snout-vent length of ♀ (mm.) ________

Egg No	Date Set	Remarks	Date Hatched	Remarks

SPECIES ______ TEMP (°F) ______ HUMIDITY(%) ______ [illegible] ______

CLUTCH NO ______ ♀ COLLECTED, DATE ______ LOCALITY ______

Egg No.	Date Set	Remarks	Date Hatched	Remarks

Cnemidophorus tigri

Cnemidophorus tigris

SPECIES Cnemidophorus tigris TEMP (°F) 90 HUMIDITY % 92 EGG TURNING none

CLUTCH NO 1 # COLLECTED DATE 5/17/58 LOCALITY 8 mi. S. of Barstow, San Bernardino Co., Calif.

Egg No	Date Set	Remarks	Date Hatched	Remarks
1	7/16/58	All eggs somewhat dessicated when found at 0800	—	Mold on outside, so opened 7/19/58. No embryo seen; yolk runny.
2	"		—	Opened 7/21/58. No embryo.
3	"		—	Opened 7/21/58. No embryo.

Crotaphytus collaris

Crotaphytus collaris

SPECIES Crotaphytus collaris #2 TEMP (°F) 90 HUMIDITY (%) 92 EGG TURNING none

CLUTCH NO. 1 ♀ COLLECTED DATE 5/17/58 LOCALITY 8 mi. S. of Barstow, San Bernardino Co., Calif.

Egg No.	Date Set	Remarks	Date Hatched	Remarks
1	8/2/58	All eggs set in pits in damp soil.	—	Humidity dropped to 74% for 2 days (8/16 to 8/17) This egg now somewhat shriveled. Died 9/10/58 (See below)
2	"		—	" " " " " Removed 9/9/58 - upon opening it was found that the embryo ~~had~~ been dead for some time. Egg was completely collapsed. All I could tell was that there had been an embryo in development.
3	"		—	9/10/58 - Heat in chamber rose to 160°F. The eggs began to shrivel so they were opened at 1430. The yolk mass was partially runny + partially coagulated.
4	"		—	The embryos were dead, the vitteline blood supply was coagulated ~~&~~ the skin was coming off the embryos. It is possible they died 9/9/58 when the heat rose to 112°F momentarily. The bodies were very soft + white with the color returning somewhat after they were placed in formalin.

Dipsosaurus dorsalis

Dipsosaurus dorsalis

SPECIES Dipsosaurus dorsalis TEMP (°F) 90 HUMIDITY (%) 96 [illegible] none

CLUTCH NO. 1 ♀ COLLECTED: DATE Apr. 20, 1958 LOCALITY Deep Canyon, Riverside Co., Calif.

Egg No.	Date Set	Remarks	Date Hatched	Remarks
1	9/2/58	Buried in N.W. corner of lizard cage.	—	Opened 9/9/58 - Collapsed + ~~mold~~-coated. Yolk dried out - No sign of embryo
2	"		—	"
3	"		—	"
4	"		—	" Yolk runny in center of mass
5	"		—	" Yolk moist in center but not runny.

Sauromalus obesus

Sauromalus obesus

SPECIES Sauromalus obesus TEMP (°F) 90 HUMIDITY 92 EGG TURNING none

CLUTCH NO 1 ♀ COLLECTED: DATE Apr. 13, 1958 LOCALITY 30 mi. S. Blythe, Riverside Co., Calif.

Egg No.	Date Set	Remarks	Date Hatched	Remarks
1	8/22/58	Several of these eggs had a little mold on them.	—	all eggs covered with mold by 8/25/58. all opened 8/28/58. The shells are rather thick and leathery (~½ mm. thick). Yolk was bright yellow (like butterscotch pudding) and rather viscous. No trace of embryos.
2	"		—	
3	"		—	
4	"		—	
5	"		—	
6	"		—	
7	"		—	
8	"		—	
9	"		—	

Sceloporus graciosus

Sceloporus graciosus

SPECIES Sceloporus graciosus TEMP. (°F) 90 HUMIDITY(%) 85 EGG TURNING none

CLUTCH NO 1 ♀ COLLECTED: DATE 6/11/58 LOCALITY 5 mi. N. Idyllwild, Riverside Co., Calif.

Egg No.	Date Set	Remarks	Date Hatched	Remarks
1	7/1/58	Rel. humidity 85% 1st 18 hrs., 92% remainder.	—	All eggs of this clutch dessicated by 7/5/58.
2	"	" " " " " "	—	All eggs set in bare Petri dishes.
3	"	" " " " " "	—	
4	"	" " " " " "	—	
5	"	" " " " " "	—	

SPECIES Sceloporus graciosus TEMP (°F) 90 HUMIDITY(%) 92 EGG TURNING none

CLUTCH NO 2 ♀ COLLECTED: DATE 6/11/58 LOCALITY 5 mi. N. of Idyllwild, Riverside Co., Calif.

Egg No	Date Set	Remarks	Date Hatched	Remarks
1	7/3/58	All eggs set on damp soil in Petri dish.	—	Egg covered with mold, so opened 7/15/58. Very shriveled. Yolk liquid but viscous. No embryo.
2	"		—	Egg opened 8/7/58. Yolk as above. Dead embryo.
3	"		—	" " " " " " " "

SPECIES Sceloporus graciosus TEMP (°F) 90 HUMIDITY (%) 92 EGG TURNING none

CLUTCH NO 3 ♀ COLLECTED DATE 6/11/58 LOCALITY 5 mi. N. of Idyllwild, Riverside Co., Calif.

Egg No.	Date Set	Remarks	Date Hatched	Remarks
1	7/7/58	Egg set on damp soil in Petri dish.	—	Egg opened 8/7/58. No trace of embryo.
2	"	" " " " " " " "	—	" " " " " " "
3	"	" " " " " " " "	—	" " " " " " "
4	"	" " " " " " " "	—	" " " " " " "
5	"	" " " " " " " "	8/10/58	Young was 23 mm. long (s-v); weighed .65 gms.

SPECIES Sceloporus graciosus TEMP (°C) 90 HUMIDITY % 92 EGG TURNING none

CLUTCH NO. 4 ♀ COLLECTED: DATE 6/11/58 LOCALITY 5 mi. N. of Idyllwild, Riverside Co., Calif.

Egg No.	Date Set	Remarks	Date Hatched	Remarks
1	7/18/58	All eggs set on damp soil in Petri dish.	—	Egg opened 8/11/58; very dessicated; Trace of embryo
2	"		—	Egg opened 8/15/58. Very dessicated; embryo rather large, but dead quite a while.
3	"		—	Egg opened 8/15/58. Somewhat crinkled; embryo was still alive.
4	"		—	Embryo still alive 8/15/58, so moist soil packed ~ 1/2 up side of egg. Egg opened 8/19/58, since embryo obviously dead (egg dark + shrunken). Humidity had dropped in chamber

Sceloporus occidentalis

Sceloporus occidentalis

SPECIES *Sceloporus occidentalis* TEMP. (°F) 90 HUMIDITY(%) 92 EGG TURNING none

CLUTCH NO. 1 ♀ COLLECTED: DATE 6/11/58 LOCALITY 5 mi. N. Idyllwild, Riverside Co., Calif.

Egg No.	Date Set	Remarks	Date Hatched	Remarks
1	7/3/58	Set in bare Petri dish.	—	Opened 7/16/58. Trace of very small embryo. Egg completely dessicated.
2	"	Set in bare Petri dish; placed in bare 30 ml. beaker 7/18/58.	—	Opened 7/26/58. 10 mm. embryo (coiled measurement) present. Became somewhat dessicated this week.
3	"	Remainder of eggs set on damp soil.	—	Opened 8/7/58. Dead embryo.
4	"		8/7/58	Disappeared inside Vapor-Temp. machinery—no measurement available.
5	"		8/7/58	"
6	"		—	Opened 8/11/58. Embryos apparently died over week-end, as all nearly ready to hatch.
7	"		—	"
8	"		—	"
9	"		—	"
10	"		—	"
11	"		—	"
12	"		—	"
13	"		—	Opened 8/11/58. Embryo dead a long time (4 mm. in diameter).

SPECIES Sceloporus occidentalis TEMP (°F) 90 HUMIDITY(%) 92 EGG TURNING none

CLUTCH NO 2 ♀ COLLECTED; DATE 7/6/58 LOCALITY Anaheim, Orange Co., Calif.

Egg No.	Date Set	Remarks	Date Hatched	Remarks
1	7/18/58	All set on damp soil.	—	Opened 8/7/58. Dead embryo.
2	"		—	"
3	"		—	Opened 8/15/58; Very dessicated; embryo dead a long time.
4	"		—	Opened 8/15/58; embryo dead short time; hemipenes well developed + everted.
5	"		—	Opened 8/15/58; egg slightly crinkled; embryo still alive.
6	"	1/2 covered with moist soil 8/15/58.	—	Opened 8/18/58; large embryo, died since 8/15/58; Egg dark + very shriveled; yolk thick + not very moist.

Sceloporus orcutti

Sceloporus orcutti

SPECIES Sceloporus orcutti TEMP. (°F) 90 HUMIDITY (%) 92 [illegible] none

CLUTCH NO. 1 ♀ COLLECTED DATE 6/11/58 LOCALITY 3 mi. E. Jacumba, San Diego Co., Calif.

Egg No.	Date Set	Remarks	Date Hatched	Remarks
1	7/3/58	Set in bare Petri dish	—	Opened 7/15/58. Embryo dead for some time; poorly preserved — ~6mm. in diameter.
2	"	"	—	"
3	"	Set on damp soil	—	Opened 7/26/58; Very dessicated; dead embryo 6 mm. long.
4	"	"	—	" " " " " " 8 " "
5	"	"	—	" " " " " " 7 " "
6	"	"	—	" " " " " " 8 " "
7	"	"	—	" " " " " " 10 " "

Uma notata

Uma notata

SPECIES Uma notata TEMP (°F) 90 HUMIDITY (%) 96 EGG TURNING none

CLUTCH NO. 1 ♀ COLLECTED: DATE Aug. 23, 1958 LOCALITY 6 mi. W. of Glamis, Imperial Co., Calif.

Egg No.	Date Set	Remarks	Date Hatched	Remarks
1	8/24/58	eggs laid in collecting sack. Very soft shells.	—	Moldy - Opened 9/9/58 - Yolk had consistency of a hard-boiled egg. No trace of embryo present.
2	"	Very disfigured egg (lop-sided).	—	mold covered egg, so opened it 8/29/58. Rather viscous yolk mass — no embryo present.

Climatology

Climatology

Climatology

Atmospheric pressure

Bar = a force of 10^6 dynes / cm^2 (dyne = force required to accelerate 1 gm. 1 cm./sec/sec.)

Bar = 29.52 inches of Hg.

A bar is divided into millibars, each of which = 0.03 inch Hg.

Winds are designated by the direction from which it is blowing.

Moisture

One can measure water vapor in millibars.

Dew Point = 100% relative humidity (saturation point) at a given temp.

Absolute humidity = density of water vapor present (gms./$meter^3$).

Specific humidity = amount of water vapor / unit mass of air (gms./kilo).

Dew = condensation of water vapor on objects whose temperature is lower than the dew point.

Frost = condensation of water vapor on objects whose temperature is below freezing.

Snow = crystalline particles of water.

Hail = water drops repeatedly carried aloft and additional layers are frozen to it to form concentric rings of ice.

Sleet = rain falls through a freezing layer of air, freezing the rain drops as they fall.

Glaze = rain strikes objects that have temperatures below freezing, thus freezing the rain on contact.

Air composition

N_2 = 78.09% Numerous other inert gases + water vapor

O_2 = 20.95% make up the remainder.

CO_2 = 0.03%

If air is saturated with water vapor in humid tropics, the air consists of ~ 4% water vapor. 3% water vapor produces a muggy day.

Greenhouse effect

Glass transmits most of the short wavelength solar radiation, but it prevents most of the long wavelength terrestrial radiation from passing through. The absorbed portion of long wavelength radiation is converted to heat, which radiates back into the greenhouse, raising the temperature inside. The same thing happens in the atmosphere, due in large measure to the ~~CO_2~~ H_2O vapor that is present in the air.

When the medium contains particles that are smaller than the wave length of the light rays, the light rays are scattered. Therefore, short wavelengths are scattered first, producing blue sky. The principal effect of dust or haze is scattering rather than absorbing.

Solar radiation

Pyrheliometer measures solar radiation.

Maximum solar constant = 1.94 gm. cal./cm²/min. This is equivalent to 4.5 million horsepower/mile.² This figure will vary ± 2%. The average solar constant for the entire year = 0.485 gm. cal./cm²/min.

Incoming solar radiation (short wave) reaching the earth's atmosphere is distributed as follows:

25% is lost through reflection without reaching the earth.
9% is scattered back to space.
19% is absorbed by the atmosphere on its way through.
24% is directly absorbed at the earth's surface.
17% is diffused through clouds, etc. before reaching the earth.
6% is scattered to earth.

Thus, 66% reaches the earth, 34% is lost without effect

at the earth's surface. 19% simply warms the atmosphere so that actually only 47% reaches the earth's surface.

Of the 66% that reaches the earth's surface or is retained in its atmosphere, all becomes converted to long wavelength (terrestrial) radiation. It becomes distributed as follows:

101 units are absorbed by water vapor in the atmosphere as this radiation attempts to leave the earth.

18 units escapes to space through a narrow band of wave lengths for which water is transparent.

23 units escapes to the atmosphere as heat (evaporation, transpiration)

10 units escapes to heat the atmosphere by convection (turbulence).

105 units is retransmitted by the atmosphere back to the earth's surface as infra-red rays.

48 units escapes to space as infra-red rays.

The greatest heat source at the earth's surface is the long wavelength radiation that is returned from the atmosphere. The greatest loss of heat is through the long wavelength radiation to the atmosphere from the earth's surface. The transfer of heat on the earth from an area of net heat gain (0-40° latitude) to the area of net heat loss (40°-90° latitude) occurs through air movement. Some occurs by water movement, but this is rather slight.

Temperature distribution

There is decreasing temp. with increasing latitude. There are greater temp. differences in the northern hemisphere because there are greater land masses present in this hemisphere. The general circulation

of the atmosphere is greater in winter than in summer because of the greater differences in temp. in winter.

Large bodies of water tend to stabilize air temps. nearby more than land masses do. On land, heat penetrates very little — most of the heat is at or near the surface. In water, however, the heat penetrates deeper because of water's translucence. Also, turbulence in water tends to distribute the heat more evenly. The evaporation at the surface requires heat from water. All these factors tend to keep water temps. more nearly constant.

Physical properties of air

Heating or cooling of air (by expansion or compression) occurs without any exchange of heat with the outside. This is called adiabatic change, and is thermally isolated. Any air that rises, expands; it is compressed when it descends. Movement of air occurs so rapidly that it is considered adiabatic (no transfer of heat). The capacity of air to hold water vapor decreases rapidly as the air is cooled. Precipitation occurs with the cooling of moist air.

Boyle's Law — for a constant temp., the volume of dry gas varies inversely as the pressure.

Charles' Law — for a constant pressure, the volume of dry gas is directly proportional to the absolute temp.

Expanding mass of air is cooled to the extent of the increase in volume. A contracting mass of air is heated by the work of compression performed on it. Temperature changes are considerable under these conditions. For example: an air mass expanded to 1/2 its initial pressure reduces the absolute temp. by 18%

(~50°C. in cooling from room temp.).

The dry adiabatic rate of change in temp. with increase in elevation is −1°C. for 10,293 cm. This is often rounded off to −1°C. / 100 meters, or −5.4°F. / 1000 ft. The maximum effect of water vapor as a gas (unsaturated) is to decrease the rate of cooling very slightly (~1 meter). Under saturated conditions, latent heat is released at condensation of water vapor (saturation adiabatic change). This adds heat to the dry adiabatic rate.

As air rises, it expands and cools until saturation and finally condensation occurs. At that point, heat is released at condensation, so there is a slower rate of cooling with more expansion.

Adiabatic heating and cooling is reversible as long as no water is removed from the air by condensation. If all the water vapor is removed by condensation, the air cools according to the dry adiabatic rate, so it returns to the surface at a higher temp. than when it ascended.

The greater the temp., the more condensation can be released if the air is cooled. Example: cooling from 40°C. to 20°C. can release much more condensation than cooling from 20°C. to 0°C., even though the temp. difference is the same in both cases (it is not a straight line function).

Lapse rate is the actual observed readings of temp. as altitude changes. It may or may not be the same as dry adiabatic rate. Lapse rate is considered positive if the temp. decreases with height. In the lower atmosphere the lapse rate usually but not always is positive. If temp. increases with rise in elevation, it

is called a negative lapse rate (inversion). If an air particle is warmer than its surroundings, its density will be less, so it will accelerate upward. If the particle is cooler than its surroundings, it will accelerate downward. The rate is determined by the difference in temp. of the air particle and its surroundings.

All vertical motions in the atmosphere tend to be accelerated in the same direction because of the increasing temp. difference between the particle and its surroundings. At the wet adiabatic rate the difference is increased even more than at the dry adiabatic rate. Therefore, acceleration is greater in moist than in dry air.

Air Stability Conditions

1. Stable equilibrium — this occurs when the prevailing lapse rate is less than the wet adiabatic rate (thus, the air particle is always colder than its surroundings). This occurs when the ground surface is colder than the air above. This happens in winter over the continents in middle and high latitudes, and over the oceans in summer. Winds are free of vertical turbulence, so there is little or no precipitation

2. Conditionally stable (or unstable) equilibrium — the lapse rate is greater than the wet adiabatic rate, but less than the dry adiabatic rate. It is a stable condition for unsaturated air, but unstable for saturated air. It occurs when the ground surface is warmer than the air. It occurs mostly in low latitudes, over continents in summer and over the ocean in winter in mid-latitudes. This condition produces turbulent storms, with lots of precipitation when the air is near or at saturation.

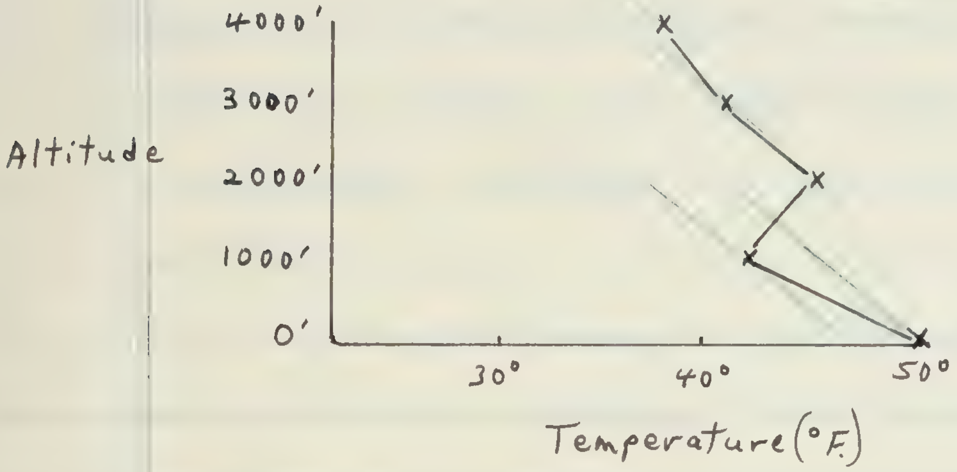
3. Neutral equilibrium - the lapse rate equals the dry adiabatic rate. Under these conditions, saturated air is unstable whereas unsaturated air is stable. This situation almost never occurs.

4. Unstable equilibrium - the lapse rate is greater (steeper) than the dry adiabatic rate for either saturated or unsaturated air. The air particle is warmer than its surroundings. Therefore, it continues to rise. This condition occurs less frequently than #1 & 2. It is restricted to the lower atmosphere (2-3 kilometers) in arid or semi-arid continental areas during periods of maximum heating of the surface. This condition produces local thunderstorms in summer, but doesn't produce any widespread storms.

5. Auto-convective equilibrium - the lapse rate exceeds -3.42°C. /100 meters (-19°F. /1000 feet). This is a rare occurrence. It results from a shallow layer of air above a strongly heated surface (sand, pavement, etc.). It is very local in extent. It produces an overturn of air without any outside source of energy. It represents extreme instability, and produces such things as "dust devils."

Any layer of air of a particular thickness will expand to a greater thickness or be compressed to a lesser thickness. A sinking layer of air spreads horizontally, while a lifted layer of air is exposed to vertical stretching. A sinking and horizontally spreading layer increases air stability (the top of air layer is heated more than the bottom of the layer by adiabatic heating). Lifting air decreases stability, since the bottom of the layer

becomes saturated before the top does. There are different conditions of stability for parcels of air at different elevations. Example:



Lapse rate	Dry adiabatic rate
0 ft. — 50°F.	50°F.
1000 " — 42°F.	44.5°F.
2000 " — 45°F.	39°F.
3000 " — 41°F.	33.5°F.
4000 " — 38°F.	28°F.

From surface to 1000′ the air is unstable because the air particle is warmer than its surroundings. From 1000′ to 2000′ the air is stable because the air particle is colder than its surroundings (inversion). From 2000′ to 4000′ the air is conditionally stable because the particle is between the dry and wet adiabatic rates.

Evaporation and Condensation

Evaporation is going on almost all of the time. Condensation, on the other hand, is not a constant thing, but is more intense and more perceptible.

Impurities in water tends to reduce evaporation. There is a loss of heat when water molecules evaporate from a water surface (latent heat of evaporation), the amount of which varies with the temp., but is not a straight line function. Example: 600 cal./gm. is lost at 0°C., but only 540 cal./gm. is lost at 100°C. Wind increases evaporation by:
1) advection - lateral movement of air (this occurs along coastlines where continental air is carried over the water)
2) turbulence - vertical movement of air. Turbulence is far more significant in this process.

Condensation can not occur in air that is throughly free of all impurities. Water molecules must have particles of some sort on which to condense (<u>condensation nuclei</u>). Such things as dust, smoke, soot, industrial pollution (smog), sea salt from ocean spray (most common hygroscopic material in the air) are often utilized by water particles.

Large particles of water are formed by the addition of other small particles. This is produced by strong vertical motion of the air. Under these conditions ice crystals form very quickly. As they fall, they melt, thereby forming a rain drop.

Saturation is produced by cool or cold air being brought over a warm surface. This brings about saturation very quickly, producing visible steaming (fogs over Great Lakes, arctic "smoke", etc.).

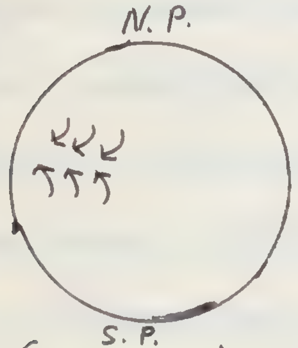
Saturation also is produced when cooling air with a given water content is cooled to a low enough temp. that saturation vapor pressure is reached. This is the more important of these 2 processes. Condensation occurs on a solid surface that is colder than the dew point of the air to which it is exposed. Example: dew forms on a cold night, but if the temp. is below the freezing point, frost occurs.

There are four processes by which air is cooled below dew point:

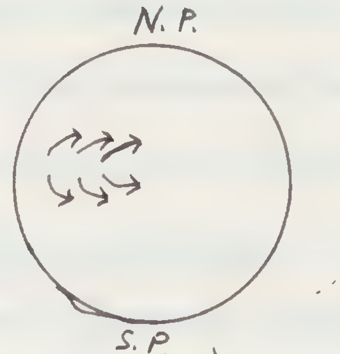
1) Cooling by conduction of heat to a cold surface
2) Direct radiational cooling of air
3) Mixing of warm and cold masses of saturated air
4) Cooling by adiabatic expansion

In hilly areas, cold air drains to low spots in the valleys at night, producing inversions in such places.

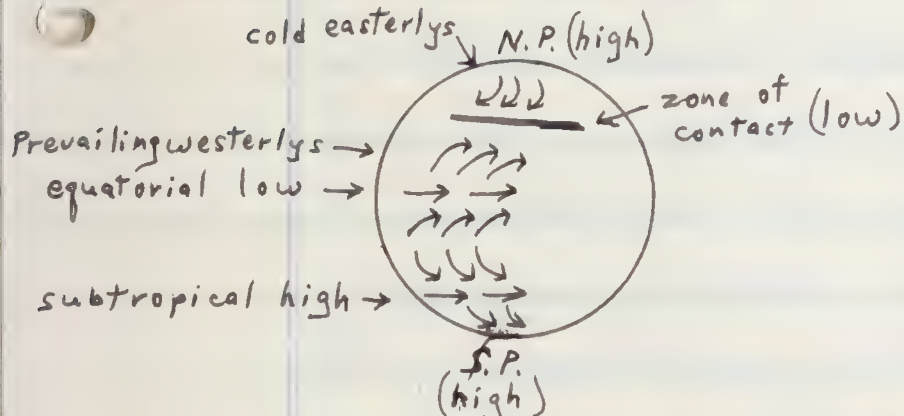
Rotation of the earth produces east winds in the lower trophosphere. Poleward moving air has an increased angular velocity. There is a reverse effect equatorward at the surface of the earth. air moves poleward aloft. Air is deflected to the right in the northern hemisphere, left in the southern hemisphere at the surface in mid-latitudes (zone of westerly winds in northern hemisphere).

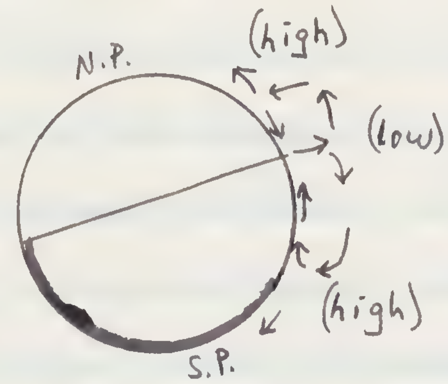


(surface)



(aloft)





(side view)

High pressure areas are maintained dynamically by the earth's rotation. The low pressure areas are maintained both dynamically and thermally. In winter the equatorial low will be slightly south of the equator, and the zone of contact shifts equatorward. (This causes rain to fall in southern Calif. in winter, due to this area being at the edge of the zone of contact when it is farthest south.) Surface features break up the zonal configuration of pressure belts — they become divided into pressure centers or pressure cells. Winds blow clockwise around

lows, counterclockwise around highs). Cells are usually in mid-ocean or mid-continent, not at the boundary between. Sub-polar oceans strengthen lows in winter due to the higher temperature of water relative to near-by land masses (ex: Alaska). Strong highs occur over sub-tropic oceans in summer for the reverse reason. Over continents there is a reversal of pressures in the change of seasons. Sub-tropical highs exist over large ocean areas throughout the year. The Aleutian low in the north Pacific and the Icelandic low in the north Atlantic are the major lows of the northern hemisphere.

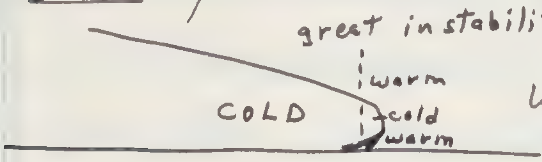
Types of fronts

1. Secondary fronts are formed orographically when a mountain barrier is lying across a strong wind. This creates a ridge of slightly higher pressure on the windward side, a slightly lower pressure on the lee side. This is a relatively unimportantant type of front. It may be important in the amount of precipitation that falls, but changes in pressure is not the cause (ex: east of Rockies, east of Appalachians, east of Sierra Nevada). No real front present.

2. Secondary front with a true front — a low pressure trough and frontal system tend to persist for some time (ex: east of Rockies in winter). It is due to strong maritime polar air from the Pacific. The temperature contrast is quite sharp — it is a warm, dry front. When this air collides with maritime (Gulf of Mexico) air, squalls and thunderstorms result. This type is not too important.

3. This type of front results from the close proximity of two air masses of quite different temperatures. It usually results when continental polar air (cold) from the Canadian shield comes into contact with maritime Carribean air (warm)

in middle and eastern United States. Frontal zones are formed on the eastern side of the continent. The lows move along the polar front to the east. The cold, heavier air tends to under-run the warm, lighter air. This is called the zone of contact or surface of discontinuity.



There are opposite winds on the two sides of the front (east on cold northern side, west on warmer southern side). When the movement is toward the warm air mass, cold air replaces the warm air (cold front); when movement is toward the cold air mass, warm air replaces cold air (warm front). It is an active front when the warm air is forced upward over the cold air to the point where condensation may occur (relative motion between the two).

4. In a passive front, no clouds form and no precipitation occurs. In a warm front the cold air mass recedes as fast or faster than the warm air approaches. In a cold front, the reverse occurs. A warm front has cirrus clouds well in advance of the front. Then alto-stratus clouds, which can produce snow, follow, in turn followed by nimbus clouds that provide rain just in advance of the front. This is due to warm air moving more rapidly than the cold air beneath. Both cold and warm fronts can be moving at the same time. Fronts are produced by changes of winds, or changes of temperature gradients.

Extreme local heating or cooling (large seasonal contrasts) produce thermally-caused secondary circulations. The larger the size of continents in mid-latitudes, the greater the seasonal circulation there will be.

A great continental high, occurring over Asia in winter, maintains a steady wind over the east of asia. Heavy rains occur in the area in summer from the monsoons. Major snowfall in the Himalaya Mts. also occurs in summer.

Most tertiary circulations are due to thermal effects.

1) Local cooling — a) a mountain breeze: upper areas are cooled more than lower slopes; cooler air moves down slope. b) at the edge of glaciers.

2) Local heating — valley breeze: warming on the lower slopes of valley during the day, air rises up slope.

3) Dry thermals — super-convective conditions produce "dust devils."

4) Direct thermals — these are due to simultaneous heating (land) and cooling (sea) of air (ex: sea breeze).

<u>Precipitation</u>

Most rain falls on or near the equator, then relatively small amounts of rain occur between 20 – 40° latitude, then rather heavy amounts fall from 40 - 60° latitude, followed by a sharp fall-off of precipitation toward the poles. This pattern doesn't hold completely, however. There is much variation within belts, due to:

1) seasonal shift that occurs in pressure belts
2) irregular distribution of land and sea
3) mountain ranges as barriers to air masses

Precipitation is usually greater over oceans than over land for any given latitude. Only from the equator to 10°S. does more precipitation fall on land than on sea.

The Climatic Symbols of Köppen (1936)

(Monthly temperatures in this table mean average monthly temperatures. The high sun, or summer, season for northern hemisphere stations is May-October; low sun, or winter, November-April)

Symbol	Name	Definition	Description	Remarks
A	tropical	coldest month over 18°C (64.4°F)	no winter	
B	dry	evaporation exceeds precipitation	too dry for growth of forests	
BS	steppe	see chart #1 at end of table	precipitation insufficient for forests; grass and open brush instead. Precipitation very low, vegetation very scanty.	
BW	desert			
C	mesothermal	coldest month between 18°C and -3°C (64.4°F & 26.6°F) and at least one month over 10°C (50°F)	mild winter	
D	microthermal	coldest month below -3°(26.6°F); at least one month over 10°C (50°F)	severe winter, snow cover or frozen ground for at least a month	
E	polar	no month over 10°C (50°F)	no summer, no trees	
ET	tundra	warmest month between 0° & 10°C (32° & 50°F)	warmest month above freezing, some vegetation	
EF	frost	no month above 0°C (32°F)	perpetual frost, lifeless	
m	transition monsoon	w in precipitation, f in vegetation, see chart #2 end of table	dry in winter with high yearly rainfall and rain forest	For A climates
w	low-sun dry	see chart #2 at end of table		For A climates
w	winter dry	driest month less than 3 cm. and rainiest summer month 10x precipitation of driest winter month	dry in winter, precipitation mainly in summer half year	For C & D climates & dry humid test (chart #1)

The Climatic Symbols of Köppen (Con't)

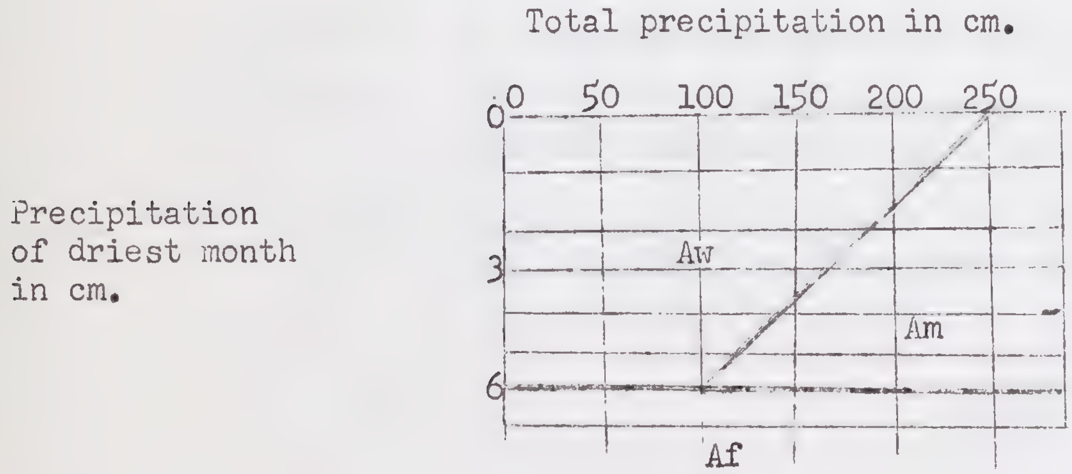
Symbol	Name	Definition	Description	Remarks
s	summer dry	driest month less than 3 cm. and rainiest winter month 3x precipitation of driest summer month	dry in summer, precipitation mainly in winter half of year	C & D climates and Dry-Humid Test (chart #1)
f	humid	neither w nor s nor m; driest month is greater than 6 cm. in A climates, otherwise it is greater than 3 cm.		
a	- - -	warmest month over 22°C (71.6°F)	summer hot	used with C & D climates
b	- - -	warmest month below 22°C (71.6°F), 4 months over 10°C (50°F)	summers moderate	
c	- - -	1-3 months over 10°C, coldest month over -38°C (-36.4°F)	summers cool	
d	- - - 1-3	1-3 months over 10°C, coldest month below -38°C	summers cool, winters extremely cold	
i	isothermal	annual range below 5°C (9°F)	little seasonal difference in temperatures	
h	hot	yearly average temperature over 18°C (64.4°F)	summers very hot, no snow or frost in winter	used only with B climates
k	cold	yearly average temperature below 18°C	summers hot, snow or frost in winter	
x	- - -	rain in early summer, late summer dry	- - - - - -	variation of Cf, Df climate
v	Cape Verde	Warmest month in fall (IX or III or later)	cool sea breezes in summer	Cs & only B
n	fog	frequent coastal fogs		
g	Ganges	warmest month before solstice		Indian & Sudanese stations

Chart #1: DRY/HUMID and BS/BW tests

	s	f	w
A, C,D			
	$r = 2t$	$r = 2(t+7)$	$r = 2(t+14)$
BS			
	$r = t$	$r = t + 7$	$r = t + 14$
BW			

r = annual depth of precipitation in cm. (1" = 2.54 cm.)
t = average temperature for the year in °C

Chart #2: Rainfall regime of "A" climates



The Köppen Climatic Classification

A. Procedure in Classifying a Climate.

1. Is the station E?
   If so, is it ET or EF? if not-

2. Is the station B?
   To determine this, it is first necessary to determine the seasonality of precipitation, s, f, or w. Then test for B (Chart #1). If so, is it BS or BW? If one of these, then is it h or K. Do i, n or v apply? If not B then-

3. Is it A, C, or D?
   If A, is it f, m or w. (Chart #2). If one of these, do i or g apply? If C, is it f, s or w (as previously determined before testing for B), and is it a, b, or c? Do g, i, x, or v apply? If D is it f, s, w, and is it d, a, b, or c? Does x apply?

B. Major Letter Combinations.

E climates: ET, EF

B climates: BSh, BShs, BShw; BSk, BSks, BSkw; BSn
BWh, BWhs, BWhw; BWk, BWks, BWkw; BWn

A climates: Af, Afi, Am, Ami; Aw, Awi, Awg, Awgi

C climates: Cfa, Cfb, Cfc; Cfbi, Cfci, Cxa
Csa, Csb, Csbi, Csbn, Csbnv; Cwa, Cwb, Cwbi, Cwg

D climates: Dfa, Dfb, Dfc, Dfd; Dsb
Dwa, Dwb, Dwc, Dwd; Dxa, Dxb

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